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The impact of type of manual medication cart filling method on the frequency of medication administration errors: A prospective before and after study

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ABSTRACT

Background: The medication cart can be filled using an automated system or a manual method and when using a manual method the medication can be arranged either by round time or by medication name. For the manual methods, it is hypothesized that the latter method would result in a lower frequency of medication administration errors because nurses are forced to read the medication labels, but evidence for this hypothesis is lacking.
Objectives: The aim of this study was to compare the frequency of medication administration errors of two different manual medication cart filling methods, namely arranging medication by round time or by medication name.
Design: A prospective, observational study with a before–after design.
Participants and settings: Eighty-six patients who stayed on an orthopaedic ward in one university medical centre in the Netherlands were included.
Methods: Disguised observation was used to detect medication administration errors. The medication cart filling method in usual care was to fill the cart with medication arranged by round time. The intervention was the implementation of the second medication cart filling method, where the medication cart was filled by arranging medicines by their names. The primary outcome was the frequency of medication administrations with one or more error(s) after the intervention compared with before the intervention. The secondary outcome was the frequency of subtypes of medication administration errors.
Results: After the intervention 170 of 740 (23.0%) medication administrations with one or more medication administration error(s) were observed compared to 114 of 589 (19.4%) before the intervention (odds ratio 1.24 [95% confidence interval 0.95–1.62]). The distribution of subtypes of medication administration errors before and after the intervention was statistically significantly different ($p < 0.001$). Analysis of subtypes revealed more omissions and wrong time errors after the intervention than before the intervention. Unauthorized medication errors were detected more frequently before the intervention than after the intervention.

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Conclusion: The frequency of medication administration errors with the medication cart filling method where the medication is arranged by name was not statistically significantly different compared to the medication cart filling method where the medication is arranged by round time.

What is already known about the topic?

- Medication errors occur frequently, especially prescribing and administration errors.
- The type of distribution system influences the risk of medication administration errors; the use of an automated system for example can reduce the frequency of medication errors, but not all hospitals will be able to afford automated dispensing machines.
- There is a lack of prospective studies evaluating the effect of different manual medication cart filling methods on the frequency of medication administration errors.

What this paper adds

- The frequency of medication administration errors was not influenced by the type of manual method for medication cart filling: medication arranged by round time and by medication name.
- The distribution of the subtypes of medication administration errors was statistically significantly different between the two medication cart filling methods.
- Omission and wrong time errors were detected more frequently when the medication cart was filled by medication name; unauthorized medication errors were detected more frequently when the medication cart was filled by round time.

1. Introduction

Proper use of medication is crucial for optimal medical treatment, but medication errors occur frequently, especially prescribing and administration errors (Bates et al., 1995; Ghaleb et al., 2010; Leape et al., 1995; Lewis et al., 2009; McDowell et al., 2009). Medication administration is a critical moment because it is the last stage in the medication distribution process. In earlier steps errors can be corrected by the healthcare worker in the next step (e.g. dispensing errors can be corrected by nurses). After the administration of medication, only alert patients may notice an error. When a patient is not alert, this last possibility of correction fails and therefore medication administration errors have a great likelihood to result in patient harm (Krähenbühl-Melcher et al., 2007; van den Bemt and Egberts, 2007).

The type of distribution system used in a hospital influences the risk of medication administration errors (Colen et al., 2003; Guchelaar et al., 2006). For example, in a study comparing different drug distribution systems, the unit dose packaging system was associated with the lowest medication administration error rate (Taxis et al., 1999). Another aspect of the distribution system that may be important with respect to the risk of medication errors is the medication cart filling method.

In the medication cart, the medication is filled for 24 h for the patients who stay on the ward. There is a separate tray for each patient. The medication cart can be filled using an automated system or a manual method. When using a manual method, the medication can be arranged either by round time or by medication name. A reason to use the latter manual medication cart filling method is that the nurse has to actively select the correct medication for that round time. In contrast when medication is arranged by round time and all filled medication may be administered without another check. Thus, hypothetically the manual method of filling the medication cart by medication name could be associated with a lower frequency of medication errors. Evidence for this hypothesis is lacking.

Studies have been published on the effect of automated medication cart filling systems when compared to manual filling methods but with inconclusive results (Barker et al., 1984; Kratz and Thygesen, 1992; Colen et al., 2003; Chapuis et al., 2010). However, the influence of the method of cart filling in manual methods (e.g. by round time or by medication name) has not been studied. This information is important, because not all hospitals will be able to afford automated systems and thus the safest method of manual filling needs to be explored. Therefore, the objective of this study was to compare the frequency of medication administration errors of two manual medication cart filling methods, namely arranging medication by round time or by medication name.

2. Methods

2.1. Setting and study population

The study was performed in the Erasmus Medical Centre in Rotterdam, The Netherlands, from May to July 2009. It took place on an orthopaedic ward with a maximum capacity of 30 beds, spread over two corridors. All patients who stayed on this ward during the study period were included. The study was part of the common health service processes of this institution not influencing patient integrity and therefore Medical Ethical Commission approval was not required according to Dutch law. All patient data were processed anonymously.

2.2. Study design

The study was a prospective, observational study with a before–after design. Medication administrations were observed in two periods of ten days, excluding the weekends, which were divided by an intervention period of two weeks. The first measurement period of ten days

concerned usual care, namely the use of the medication cart filling method with medication arranged by round time. The intervention was the implementation of the second medication cart filling method, where the medication cart was filled by arranging medicines by their names. Two weeks after implementing the intervention the second measurement period of ten days started.

2.3. Medication distribution system

The Erasmus MC used computerized physician order entry. On the orthopaedic ward, medication orders were entered by doctors at three set times a day. After authorization, the medication orders were printed on labels. These labels were put on the medication records of the patient by the nurses. These medication records were used for filling the medication cart for the next 24 h, which was performed during the night shift. The medication cart consisted of separate trays. Each patient had his own tray, which was divided in several compartments. With the cart filling method by round time, each compartment was used for filling the medication of one round time. The number of compartments containing medication was equal to the number of round times the patient was prescribed medication. With the cart filling method by medication name, each compartment was used for one medication name. For each patient, the number of compartments containing drugs was equal to the number of prescribed medicines.

During the day, the medication was administered by another nurse than the nurse who filled the medication cart. This resulted in the mandatory double check. The nurse collected the medication for the patient for that round time from the medication cart, on the basis of the medication record. After checking the collected medication against the information on the medication record, it was administered to the patient and the nurse signed the medication record. The orthopaedic ward used the following round times: 0:00, 6:00, 8:00, 10:00 and 12:00 a.m. and 2:00, 6:00 and 10:00 p.m.

2.4. Definitions and classifications

A medication error was defined as any preventable event that may cause or lead to inappropriate medication use or patient harm while the medication was in the control of the healthcare professional, patient or consumer (van den Bemt and Egberts, 2007). Medication administration errors were defined as the category of medication errors which were made in the last stage of the medication distribution process, namely the stage of administering medication to the patients (van den Bemt et al., 2000). Medication administration errors were classified in subtypes according to the National Classification System of the Dutch Association of Hospital Pharmacists (van den Bemt and Egberts, 2007), as is shown in Table 1. The subtype 'wrong preparation' was not included in this study, because no influence from the medication cart filling method was expected on the frequency of this subtype of medication administration errors.

Table 1
Classification of medication administration errors according to the National Classification System of the Dutch Association of Hospital Pharmacists (van den Bemt and Egberts, 2007).

Omission (prescribed medicine not administered)
Intake of unordered medication
Wrong preparation
Wrong dosage form
Wrong route of administration
Wrong administration technique
Wrong dosage
Wrong time (at least 60 min early/late)

In addition to the subtypes in the table, we used an additional subclass of administration errors which was typical for hospitals using computerized physician order entry, namely administering medication based on an unauthorized medication order ('unauthorized medication error'). This subclass was potentially less severe than an unordered drug error, because in that case the nurse administered medication without any order. For unauthorized medication errors a handwritten or oral medication order issued by the physician existed, but it was not entered and authorized in the computer (yet).

2.5. Data collection

Data obtained from patients included the patient identification number, gender, date of birth, dates of hospital admission and discharge and in case of surgery the date of the surgery. As ward characteristics a number of data were collected that can be seen as a measure of workload, namely the mean number of patients staying on the ward per day, the mean number of newly admitted patients per day, the mean number of patients discharged per day, the mean number of patients having surgery per day, the mean number of drugs per patient per day and the mean number of medication administrations per patient per day. For each observed medication administration the observer noted if it was accomplished by a qualified nurse or by a trainee. The percentage of qualified nurses was used as a ward characteristic besides workload. Both patient and ward characteristics were collected as potential confounders.

The medication administration errors were detected with the disguised observation technique. An observer accompanied the nurses and observed each medication administration at the bedside of the patient. The observer wrote down his observations on a specially designed form. The nurse was not aware of the exact objective of the observations ('disguised') (Allan and Barker, 1990). Nurses were told that the study was done to optimize the drug distribution system. If the observer determined a serious medication administration error which could result in patient harm, the observer interrupted the medication administration. After the observation the data on the form were compared with the medication order data in order to identify medication administration errors.

Medication administrations were observed at different round times by a total of four observers. The observers were medical and pharmaceutical students and were independent from the hospital. All observers had an initial

training period. This consisted of training in using the specially designed data collection form in order to make sure it was filled out in a uniform way. The second part of the training period consisted of a practice training in observation on the ward. The training period was concluded by carrying out some test observations before the study started. These test observations were not included in the study. One corridor of the ward was observed on each day of the study.

2.6. Outcomes

The primary outcome was the frequency of medication administrations with one or more error(s) after the intervention compared to the pre-intervention period. These frequencies were calculated using the following formula: number of observed medication administrations with one or more medication administration error(s)/ number of observed medication administrations × 100%.

The secondary outcome was the frequency of subtypes of medication administration errors (compared to the total frequency of medication administration errors) comparing the two measurement periods. For the secondary outcome, more than one error per medication administration could be included.

2.7. Data analysis

The collected data were processed using Microsoft Office Access and Excel 2003 and statistically analysed using SPSS statistical package version 15.0. For the differences in patient characteristics in the population before and after the intervention, the continuous variables with a normal distribution were tested with the Student's *t*-test, the continuous variables with a non-normal distribution were tested with the Mann–Whitney test and the categorical variables were tested with the Chi-square test. To examine the distribution for normality, the Kolmogorov–Smirnov test and the Shapiro–Wilks test were used. For the primary outcome, univariate logistic regression analysis was used, calculating the odds ratio (OR) with a 95% confidence interval (95CI). If any patient characteristic showed a statistical significant difference, the primary and secondary outcomes were adjusted for these characteristics using multivariate logistic regression analysis, provided that the beta coefficient was changed with more than 10% in the multivariate model using the enter method for the introduction of potential confounders in the model. For the secondary outcome, a Chi-square test was used to analyze the distribution of the different subtypes of medication administration errors before and after the intervention. A p-value of <0.05 was considered to be statistically significant for all analyses.

2.8. Power calculation

With an estimated error frequency of 20% in the round time method, and assuming a 40% reduction in medication errors when using the medication name method (this reduction is based on the average reduction after implementation of automated medication carts (Barker et al., 1984; Chapuis et al., 2010)), an alpha of 0.05 and power of 0.8, the number of administrations to be observed per measurement period would be 354. A two week measurement period should be sufficient to reach this number of observations.

3. Results

Eighty-six patients were included in this study; five patients remained on the ward during both measurement periods or were re-admitted in the second measurement period. Table 2 shows that patient and ward characteristics did not differ between the two measurement periods. This means that the primary and secondary outcomes did not need adjustment for these characteristics.

One of the observers intervened on one occasion during the post-intervention period. The observer detected an omission (β-blocker), while an unordered medicine (ezetimib) was administered with the wrong dose (the dose of the β-blocker). The medication record was signed for administration of the β-blocker. After discussing the

Table 2
Patient and ward characteristics before and after the intervention.

	Pre-intervention period	Post-intervention period	P-value
Patient characteristics ($n = 86$)[a]			
Number of patients	45	46	
Age, years (mean ± SD)	57.5 ± 18.4	51.7 ± 18.6	0.14[b]
Gender, % male	64	52	0.24[c]
Duration of admission, days (mean ± SD)	9.2 ± 8.0	11.0 ± 8.3	0.29[b]
Ward characteristics—workload			
Number of patients at the department (mean ± SD)	17.6 ± 5.8	21.3 ± 2.8	0.09[b]
Number of admissions per day (mean ± SD)	2.6 ± 2.4	2.2 ± 1.6	0.66[b]
Number of discharges per day (mean ± SD)	1.7 ± 1.4	1.6 ± 1.6	0.74[d]
Number of surgeries per day (mean ± SD)	2.3 ± 1.8	2.6 ± 1.1	0.65[b]
Number of drugs per patient per day (mean ± SD)	6.9 ± 3.4	8.0 ± 3.6	0.13[b]
Number of medication administrations per patient per day (mean ± SD)	10.7 ± 5.3	12.6 ± 5.2	0.09[b]
Ward characteristics—nurse qualification			
Qualification of the nurses, % qualified nurse	80	77	0.21[c]

[a] Five patients remained on the ward during pre- and post-intervention period or were re-admitted in the post-intervention period.
[b] Student's *t*-test.
[c] Chi-square test.
[d] Mann–Whitney test.

Table 3
Frequency of medication administrations with one or more medication administration error(s) before and after the intervention.

	Pre-intervention period concerns drugs arranged by round time	Post-intervention period concerns drugs arranged by medication name	OR (95CI)[a]
Number of observed medication administrations ($n = 1329$)	589	740	
Number (frequency) of observed medication administrations with one or more medication administration error(s)	114 (19.4%)	170 (23.0%)	1.24 (0.95–1.62)

Abbreviations: OR, odds ratio; 95CI, 95% confidence interval.
[a] Univariate logistic regression analysis.

Table 4
Frequency of subtypes of medication administration errors before and after the intervention.

	Pre-intervention period Drugs arranged by medication name	Post-intervention period Drugs arranged by round time
Total number of detected medication administration errors ($n = 295$)[a]	120	175
Number (frequency) per subtype of medication administration errors		
Omission (prescribed medicine not administered)	22 (18.3%)	63 (36.0%)
Unauthorized medication error		
Retrospectively authorized by doctor	33 (27.5%)	19 (10.9%)
Not authorized by doctor	21 (17.5%)	7 (4.0%)
Wrong preparation	–	–
Wrong dosage form	12 (10.0%)	10 (5.7%)
Wrong route of administration	0	2 (1.1%)
Wrong administration technique	0	0
Wrong dosage	8 (6.7%)	5 (2.9%)
Wrong time (at least 60 min early/late)	24 (20.0%)	69 (39.4%)

$p < 0.001$ (Chi-square test for the analysis of $2 \times k$ tables).
[a] In the pre-intervention period, we observed 6 medication administrations with 2 administration errors; in the post-intervention period, we observed this in 5 medication administrations.

omission with the hospital pharmacist the decision to intervene was made.

After the intervention, 170 of 740 (23.0%) medication administrations with one or more medication administration error(s) were observed compared with 114 of 589 (19.4%) before the intervention (OR 1.24 [95CI 0.95–1.62]); this difference was not statistically significant (Table 3).

The frequency of the subtypes of medication administration errors compared to the frequency of medication administration errors for each period is described in Table 4. Before the intervention 120 medication errors were detected (6 medication administrations with two errors) and after the intervention 175 medication errors were detected (5 medication administrations with two errors). As a consequence, the total number of detected medication administration errors (Table 4) was higher than the number of observed medication administrations with one or more medication administration error(s) (Table 3). The distribution of subtypes of medication administration errors before and after the intervention was statistically significantly different ($p < 0.001$). The subtype 'unauthorized medication error' was detected more often before the intervention (17.5% of the medication administration errors) than after the intervention (4.0% of the medication administration errors). The subtype 'omission' was detected more often after the intervention (36.0% of the medication administration errors) than before the intervention (18.3% of the medication administration errors), as was the subtype 'wrong time' (39.4% of the medication administration errors versus 20.0% of the medication administration errors). There were only small differences detected for other subtypes.

4. Discussion

We studied the impact of the type of manual medication cart filling method on the frequency of medication administration errors. The two studied manual medication cart filling methods were arranging medicines by round time or by name.

The results with respect to the overall identified medication error frequencies were comparable to some other studies where the (disguised) observation technique was used for the detection of medication administration errors (Tisdale, 1986; Schneider et al., 1998; van den Bemt et al., 2002). Tisdale and Schneider both performed their studies in paediatric intensive care settings, which are known as high risk environments. They identified error frequencies of 26.9% (Schneider et al., 1998) and 17.4% for neonatal intensive care and 38% for paediatric intensive care (Tisdale, 1986). Likewise, adult intensive care research showed high error frequencies of 44.6% (van den Bemt et al., 2002). The setting in our study was a regular hospital ward, which is more comparable to the setting used by Taxis et al. (1999) and by Chua et al. (2009). Taxis showed lower error frequencies (2.4–8% depending on the type of medication distribution system) than in our study, as did Chua et al. (11.4%). It is unclear why we have found higher error rates, but the complexity of the patient group in the academic hospital setting may have contributed to this.

Literature comparing different medication cart filling methods is not available. To our knowledge our study is the first investigating this question. We found that the frequency of medication administrations with one or more medication administration error(s) did not differ between the two methods of medication cart filling.

Analysis of the subtypes of medication administration errors showed a statistically significant difference between the distribution of the frequency of the subtypes before and after the intervention. After the intervention more omissions and wrong time errors were identified. In contrast, unauthorized medication errors were detected more frequently before the intervention. Omission is caused by missing a medication administration, despite the printed medication order being present on the medication record of the patient. For this subtype of medication administration errors, nurses may be less attentive when the medication cart is filled according to medication name. In the case of the medication cart filling method according to round time, the nurse will check the medication record for a second time with more attention if medication remains in the relevant compartment (for that specific round time). This signal is not present when using the medication cart filling method by medication name. When an omission occurs, the medicine is left in the compartment. A nurse will notice this in the course of the day and administer the medicine at that time. This results in a wrong time error. Therefore, the same explanation for the more frequent occurrence of wrong time errors after the intervention can be given as for the occurrence of omissions. Most of the unauthorized medication that was administered to the patient concerned handwritten medication orders which were authorized by doctors retrospectively. Unauthorized medication was more frequently detected when the medication cart was filled by round time rather than by medication name. It is unclear why this difference occurred.

A strength of this study is to use (disguised) observation as the detection technique to identify medication administration errors. Direct observation is the best error detection method in terms of efficiency and accuracy (Allan and Barker, 1990; Flynn et al., 2002). Secondly, two medication cart filling methods are compared using the same detection technique in a prospective study, which contributes to the validity.

This study also has several limitations. Firstly, to be able to observe during as much round times as possible, several observers were used to detect the medication administrations errors. This contributes to the observation bias on account of differences between observers (Barker, 1980). However, observers were trained in a uniform way and used the same observation forms, thus minimizing this bias. Flynn et al. have shown relatively good kappa values when comparing the results of different observers (Flynn et al., 2002), although some outliers were present. We cannot exclude the possibility that some of our observers represented outliers as well and thus caused observation bias. Secondly, being observed may have influenced the behaviour of the nurses, but the literature describes that after observing a number of hours this influence disappears and therefore the influence during a ten day measurement period is negligible (Kerlinger, 1973; Dean and Barber, 2001). Furthermore, although our observation was disguised, it is likely that some nurses had an idea of the real purpose of the study. Dean and Barber have shown previously that interventions on errors (and thus revealing the true purpose of the observation) did not significantly affect the error rates measured (Dean and Barber, 2001). Therefore, we feel that loss of the disguise is not a threat to the validity of our study. Thirdly, the intervention period was short which could have resulted in medication administration errors caused because staff was not used to work with the new method yet. Fourthly, the observations were carried out on one ward of the hospital on weekdays only, limiting the generalisability to other wards and other hospitals. Fifthly, we did not assess the clinical significance of the medication administration errors, so it remains unknown whether there was a difference in severity of errors between the two measurement periods (Gallivan et al., 2008). The final limitation of this study is the incomplete information about potential confounders, such as additional nurse characteristics (e.g. years of experience). However, as most ward characteristics and nurse qualification's did not differ between both periods and because the measurement periods were planned in short succession we do not expect that major differences in unknown variables exist between both periods.

Despite the limitations, this study shows that changing the method of manual medication cart filling has no influence on medication administration error frequency. This frequency remains unacceptably high, so other methods for improving the medication administration process need to be developed. Such methods may be the use of automated medication carts or the use of barcode technology, but such techniques are expensive and may not be feasible for all hospitals. Therefore, simple non-technical solutions should also be explored. An option for this may be the use of special vests for the nurses who administer medication, containing the warning text: 'do not disturb, I am administering medication'. Future studies into the effect of such simple solutions are necessary. Other recommendations for future studies of medication administration errors in relation to the medication cart filling method, is to extend the observations of medication administrations to different wards of the hospital, to observe during the weekends, to observe for a longer period after the intervention and to assess the clinical significance of the errors. Moreover, it is recommended to collect more data on potential confounders.

5. Conclusion

The frequency of medication administration errors using the medication cart filling method where medication is arranged by medication name was not statistically different from the frequency of medication administration errors using the medication cart filling method where the medication is arranged by round time. Analysis of the subtypes of medication administration errors showed a statistically significant difference in the distribution of the medication administration errors between the two medication cart filling methods. In this study, analysis of

subtypes revealed more omission and wrong time errors when using the medication cart filling method where medication is arranged by medication name. On the other hand, unauthorized medication errors were detected more frequently when the medication cart was filled by round time.

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